Seattle City Light

AECOM

HATCH ACRES

Update on Total Dissolved Gas Mitigation Measures for Boundary Dam

by

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Introduction

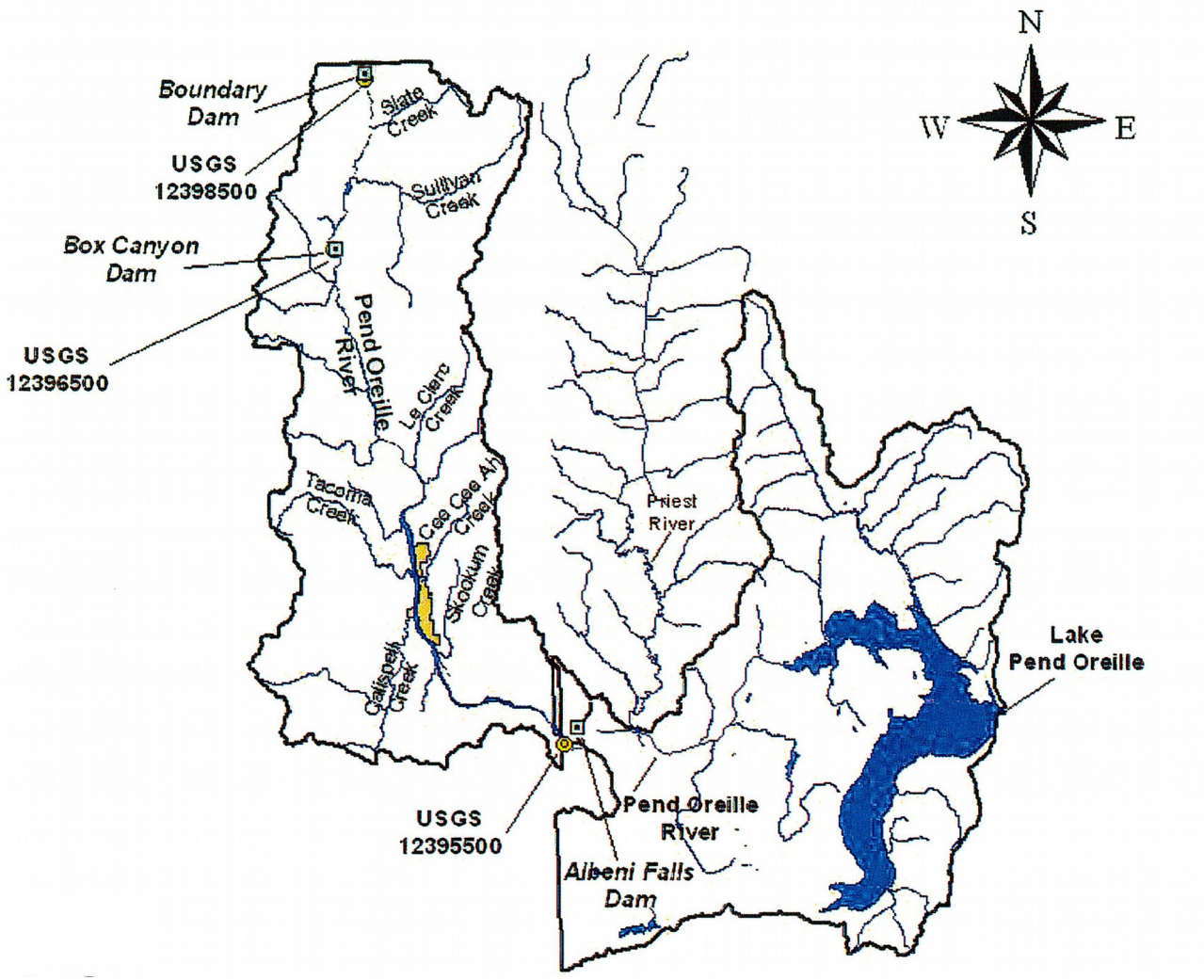
FERC license renewal for Boundary Project

- Washington Department of Ecology water quality certification
- Certification requires TDG attainment Plan above standard

Purpose of TDG studies:

- Will TDG of releases meet standard?
  - TDG < 110 % saturation at atmospheric pressure
  - Waiver if
    - Incoming TDG is greater than standard
    - Flow exceeds 7Q10 event (108,300 cfs)
- If not, develop facility and/or operational changes

Boundary Project Site Map



Project Facilities

340 ft high 740 ft long concrete arch dam

2 – 50 ft wide radial gate spillways
- combined capacity = 108,000 cfs

7 – low level slide gate sluices
- combined capacity = 252,000 cfs under 190 ft of head

6 – Francis turbine units
- hydraulic capacity = 55,000 cfs

7Q10 spill flow requiremer = 53,300 cfs

Effects of Project Operations

Operation of spill gates individually and combined at flows up to ~ 8,000 cfs each strips gas at high FBL TDG and has neutral effect at lower FBL TDG

Individual sluice operation at up to ~ 3,500 cfs each has neutral effect on tail water TDG

Staggered ops of 3 sluices may be possible

Total operational spill flow by above ~20,000 cfs versus 53,300 cfs required

Reference - Sweeney, et. al. 2008. Analysis of Operational Effects on Total Dissolved Gas Production at Boundary and Wells Dams. HydroVision 2008.

TDG Generation Mechanism

Conditions for gas transfer:

- Air available in fluid
- Large air/water surface interface available
- Pressure available to drive transfer

Spillway TDG mechanism:

- Air entrained in jet and at plunge into tail water
- Energetic flow breaks up air into bubbles
- Air bubbles carried to depth

TDG Mitigation Measures

1. Reduce air entrainment (almost impossible)
2. Reduce flow energy through head loss or energy extraction
3. Reduce jet penetration/air entrainment depth

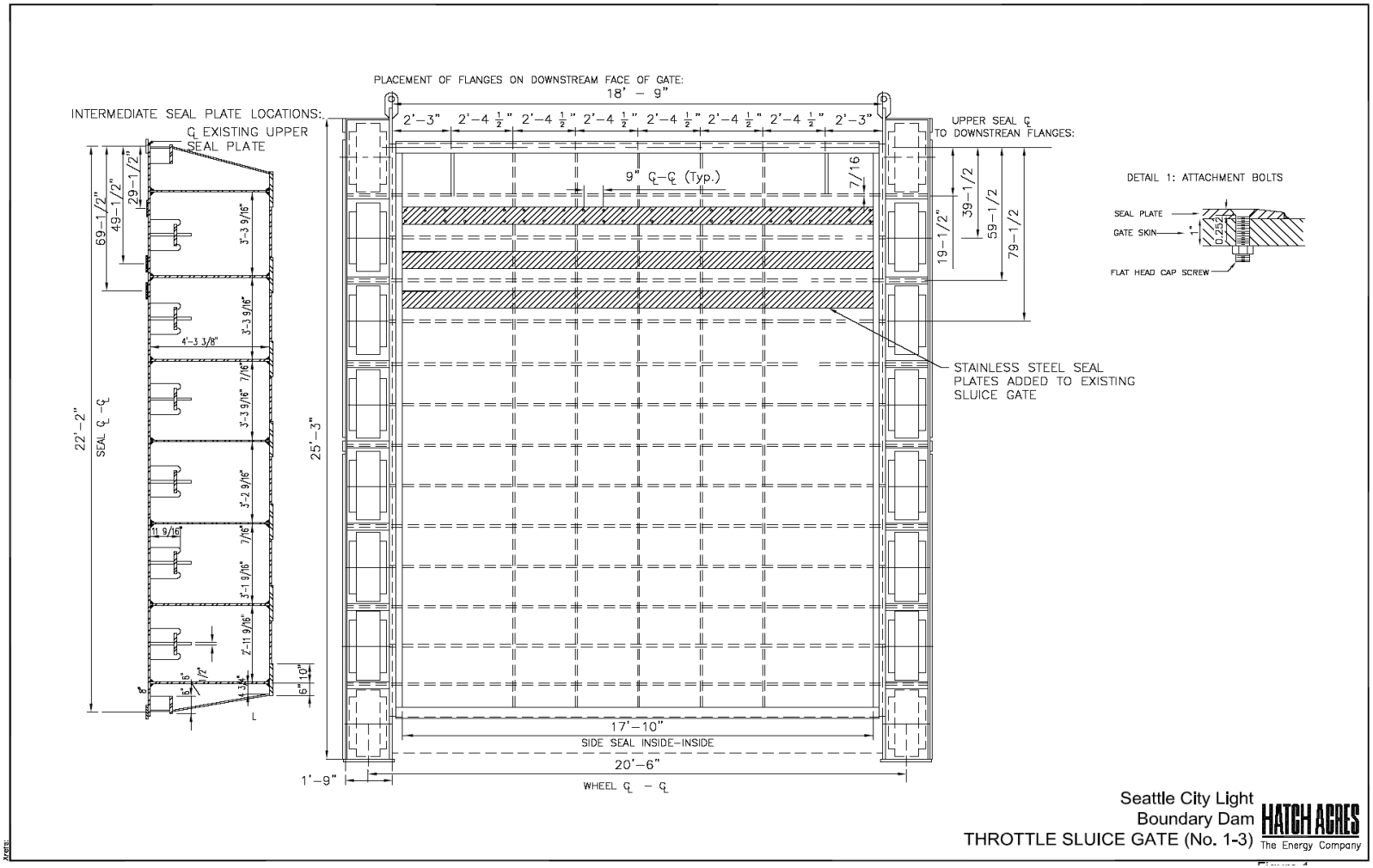
Structural Mitigation Alternatives

Structural modifications of spillways and sluices

Spread jet impact area and reduce tail water penetration

- Throttle sluice gates (modification to sealing system for partially open operations)
- Roughen sluice flow (deflectors)
- Spillway flow splitter/aerator (dentated flip bucket)

Sluiceway Modifications
Throttle Sluice Gate



Sluiceway Modifications
Attaching Seal Plates to Sluice

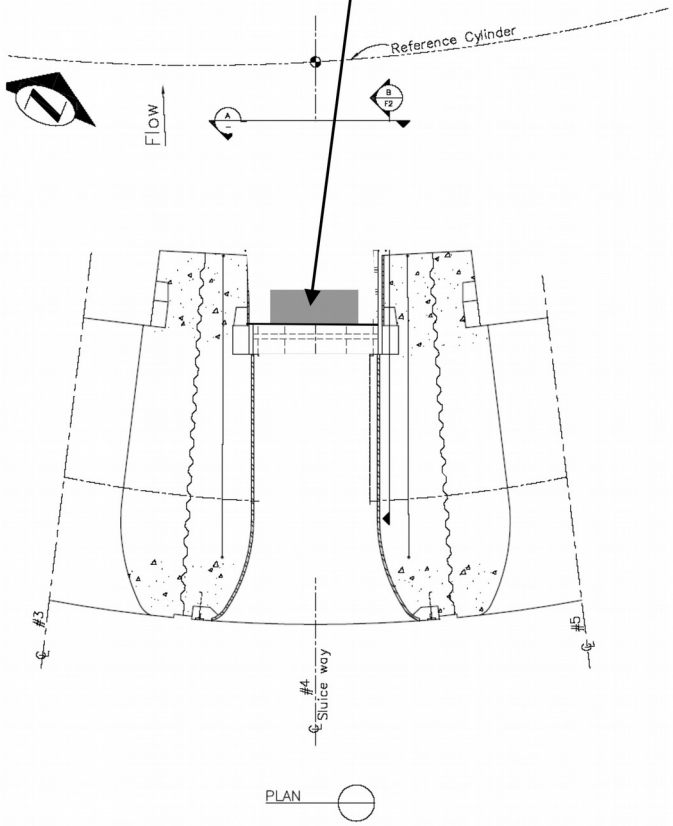
Sluiceway Modifications
Seal Plates – Before and After

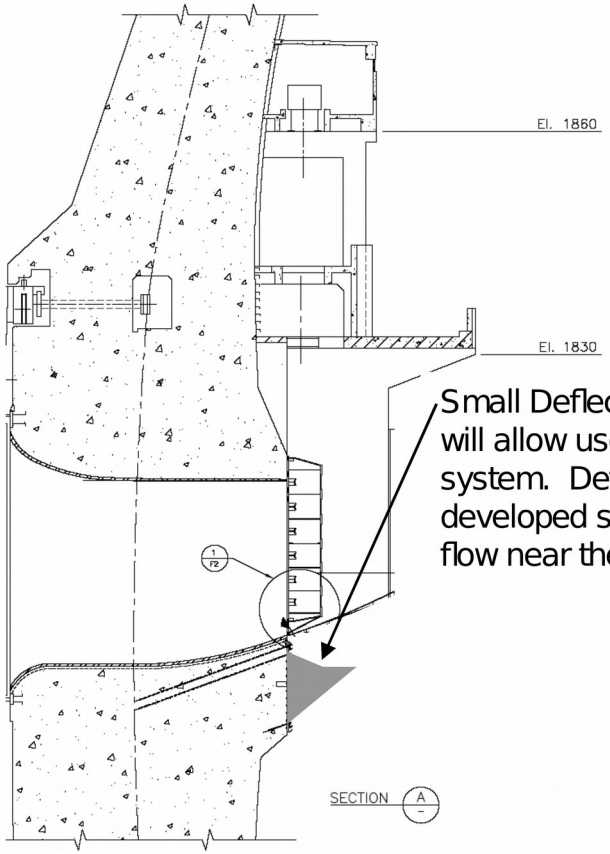
2006 Test (4-20-06) before seal plates added – top and side seal spray has beer eliminated in above picture.

Gate proof of concept test – gate sealed well – no unexpected vibration observed. November 15, 2007

Sluice Deflectors

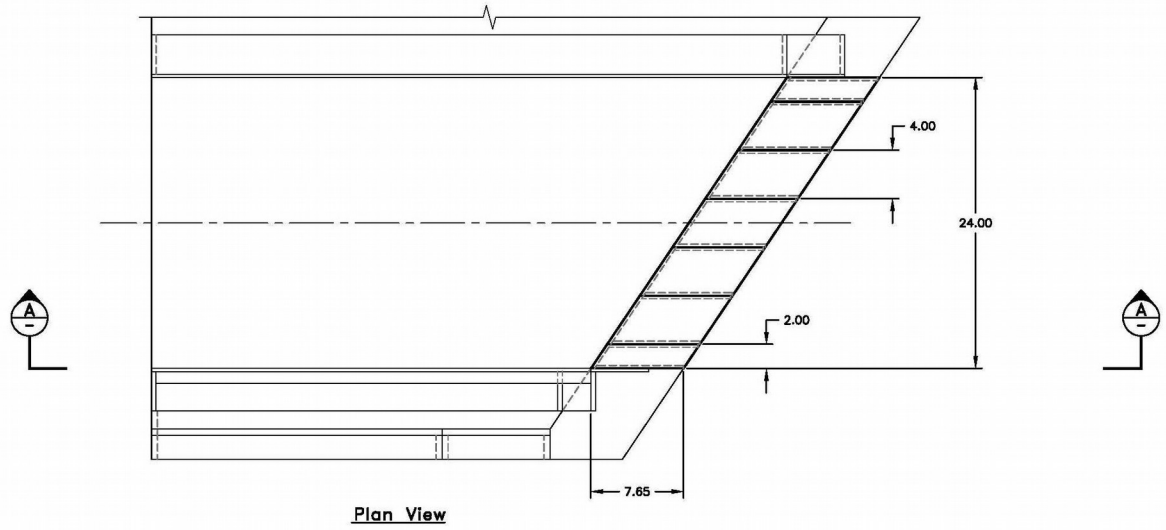
Deflector could be developed shorter to reduce spray impinging on gate slot

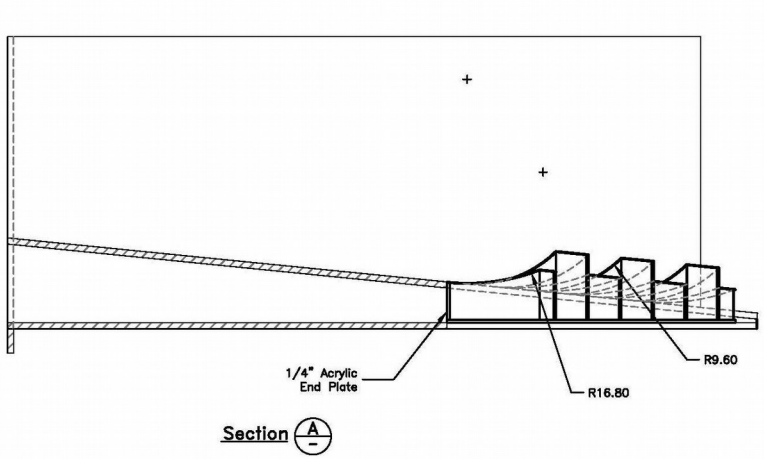


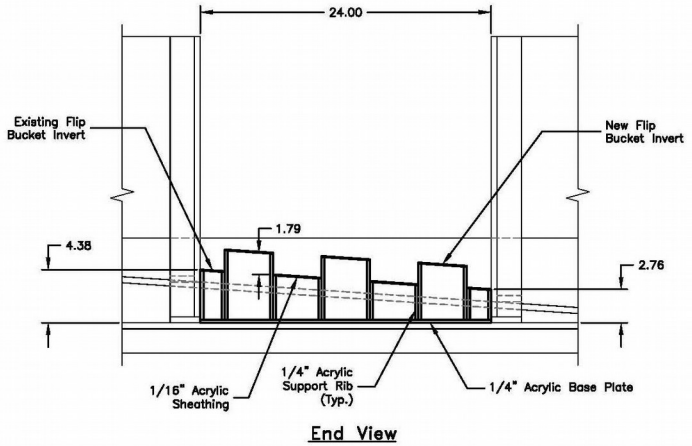


Small Deflector concept that will allow use of existing seal system. Deflector could be developed shorter to deflect flow near the dam.

Dentated Spillway Flip Bucket







Physical Model Analysis

Model Scale Selection

- 1:25
- Scaling requirements for spillway aerators
- Provides quantitative relative, not absolute information

Physical Modeling Objectives

- Test sluice and spill gate operations and modifications
- Visualize jet interactions, and quantify tail water impact areas and jet penetration
- Provide Computational Fluid Dynamics (CFD) model verification

CFD Model Analysis

CFD Modeling Objectives

- Test sluice and spill gate operations and modifications
- Incorporate into overall CFD model of project tailrace
- Provide hydrodynamic framework for overall TDG predictive model

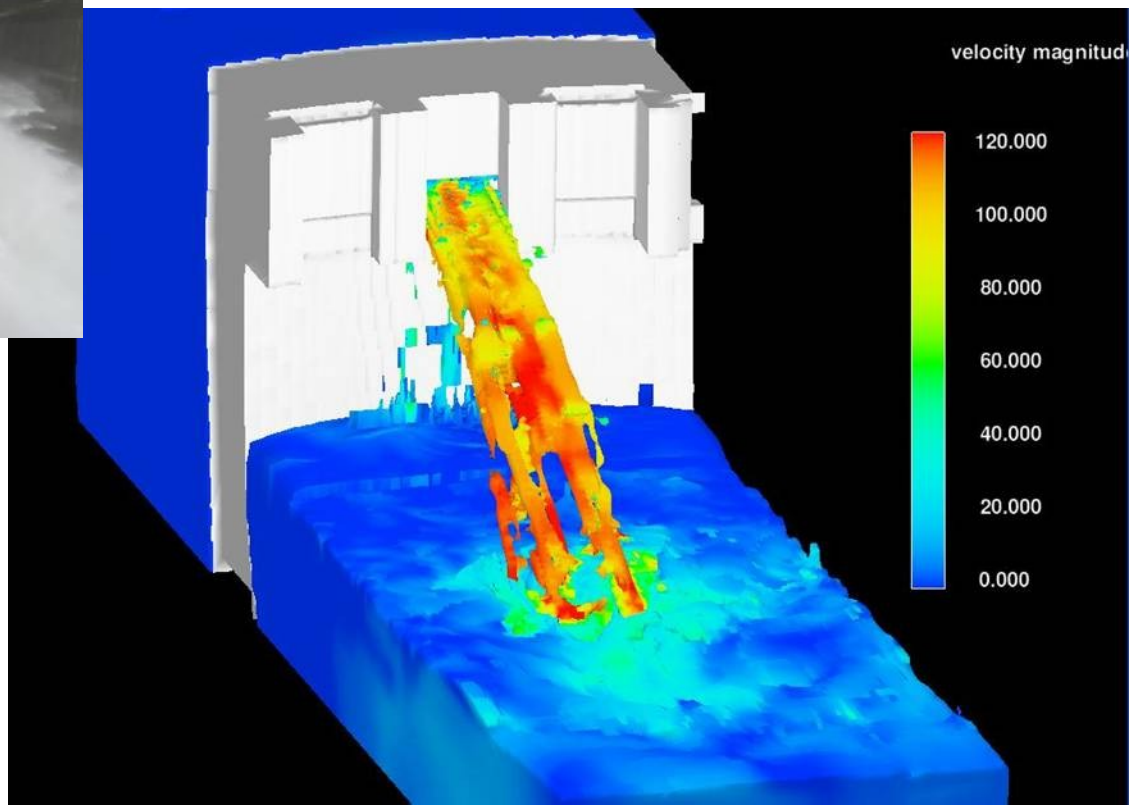
Physical Model Versus Prototype Sluice Base Case

Sluices 2 and 6 at 3,400 cfs each; Sluice 4 at 2,200 cfs

Physical Model

Prototype

CFD Model Sluice Base Case

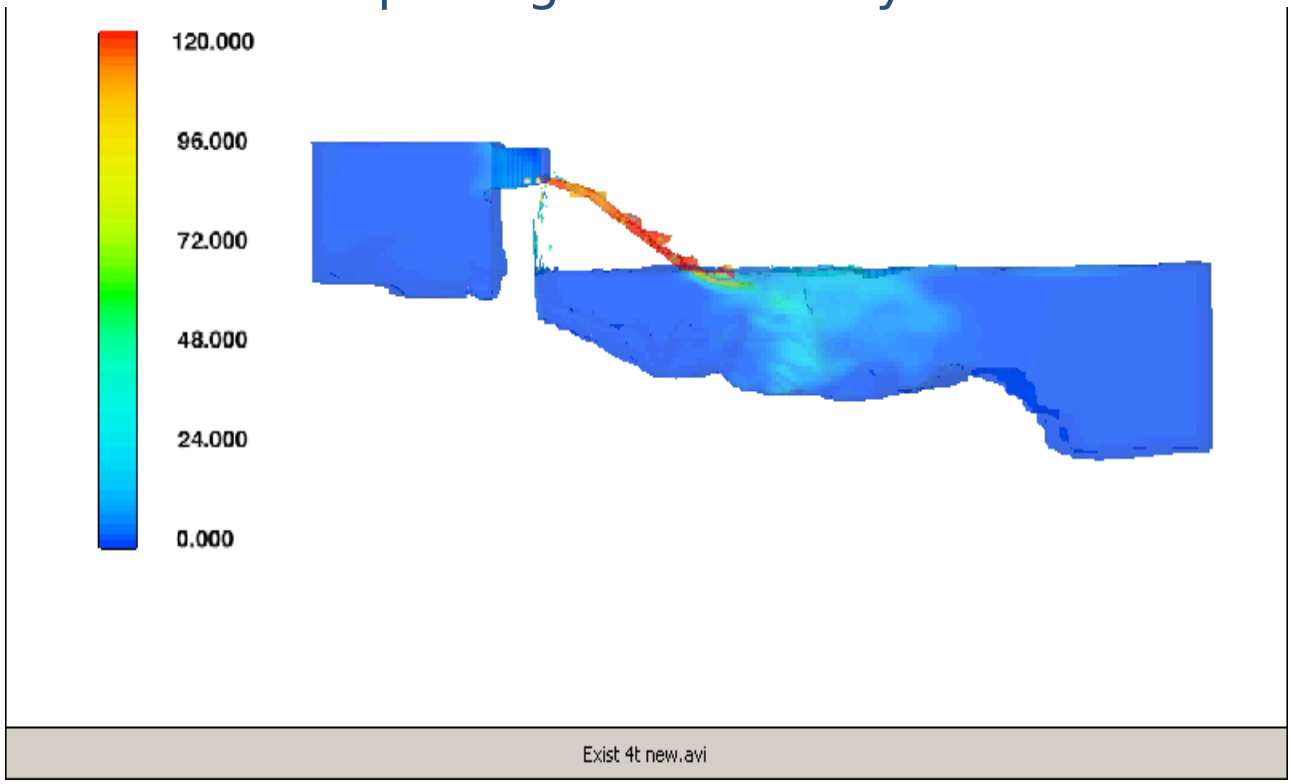


CFD Model Sluice Base Case

Existing Condition:

Various runs were conducted to establish base line condition:

- Focused on 4 ft opening of sluiceway



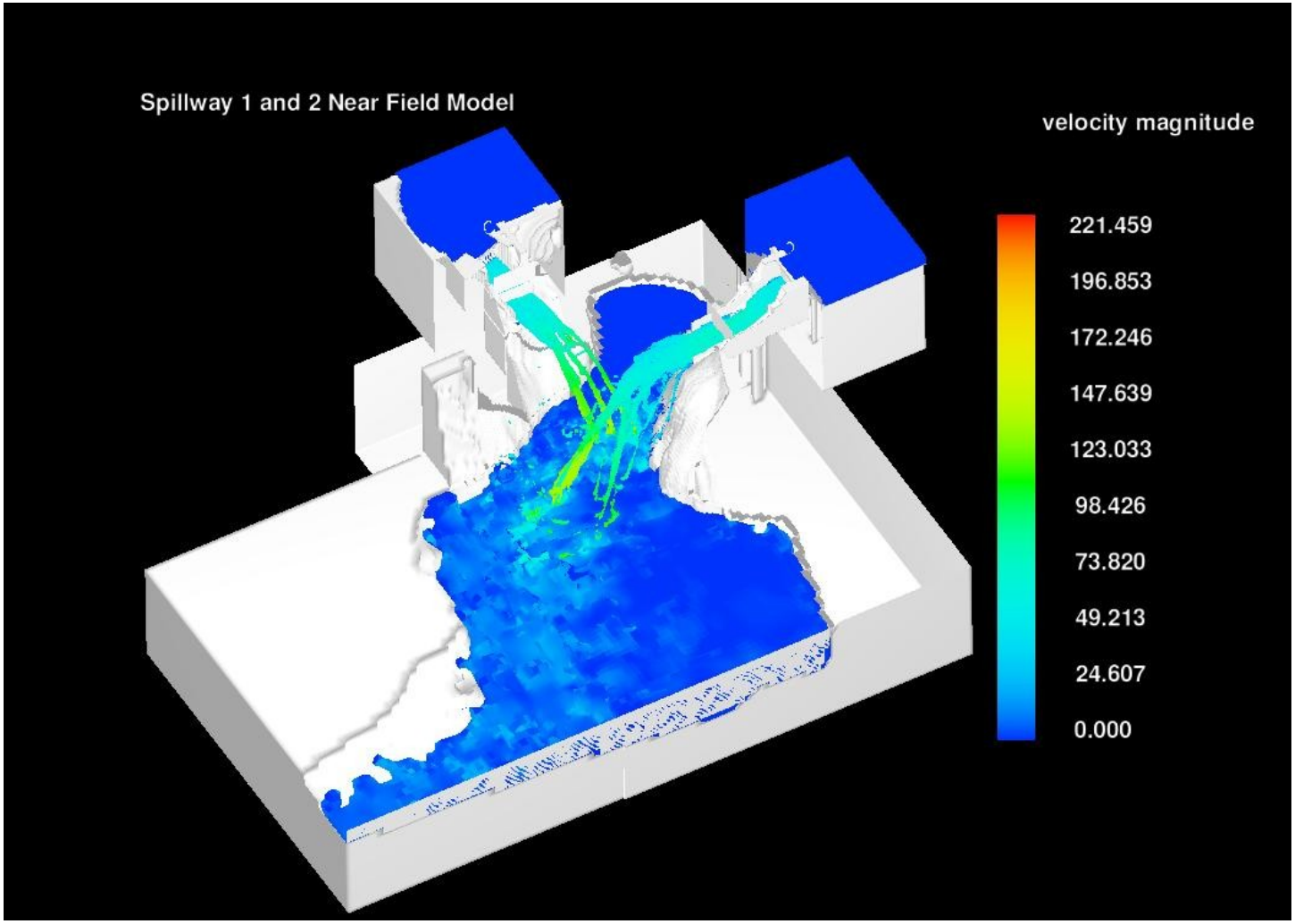
Physical Model Versus Prototype Spillway Base Case

Two Spillways at 6,500 cfs each

Physical Model

Prototype

CFD Model Spillway Base Case



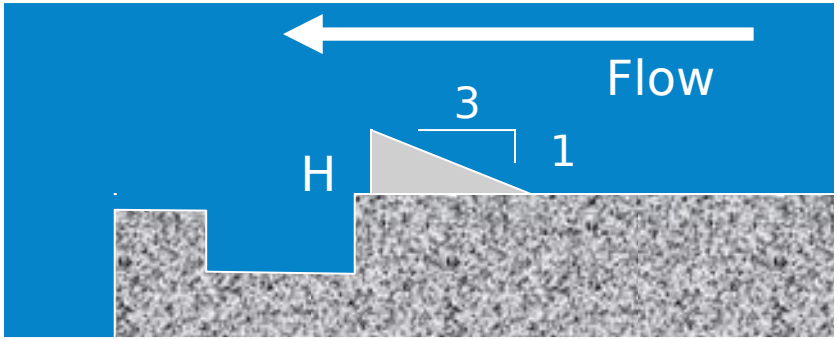
Physical Model Photo Dentated Spillway Flip Bucket

Two Spillways at 6,500 cfs each

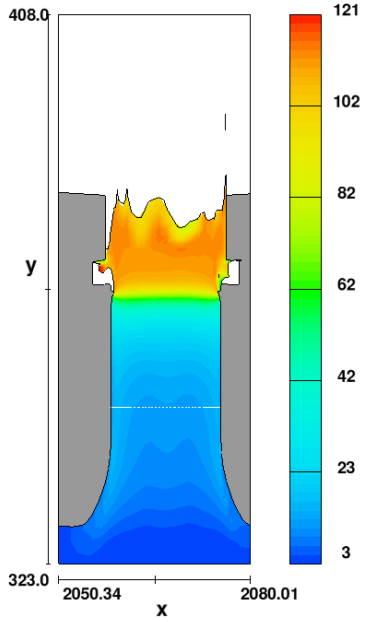
Baseline Case

Dentated Flip Bucket Spillway 1

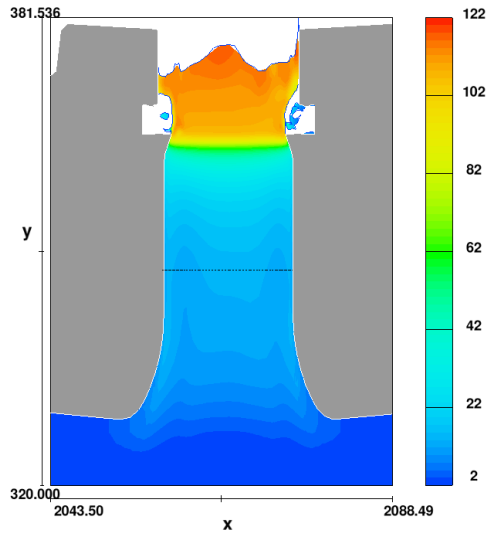
CFD Model – Gate Slot Deflectors



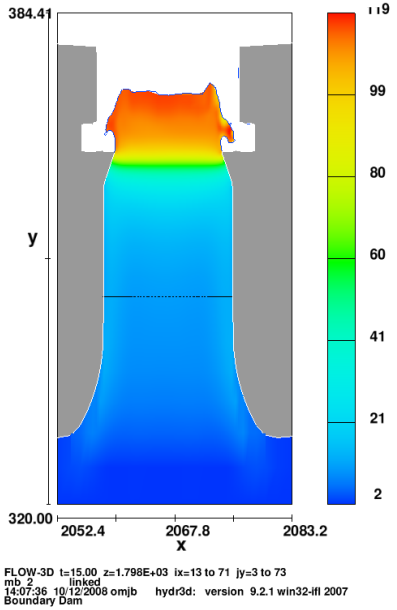
H = 6”



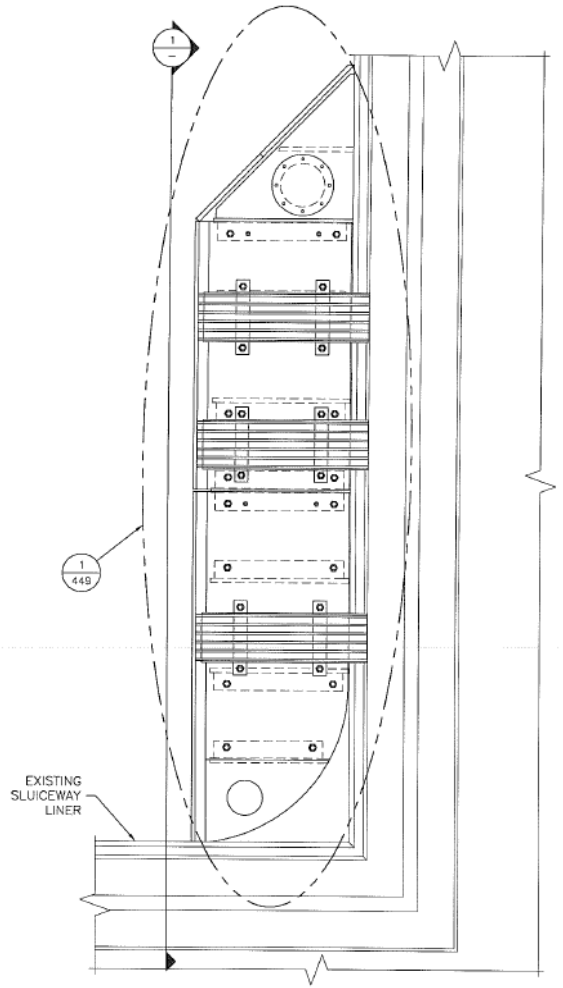
H = 12”

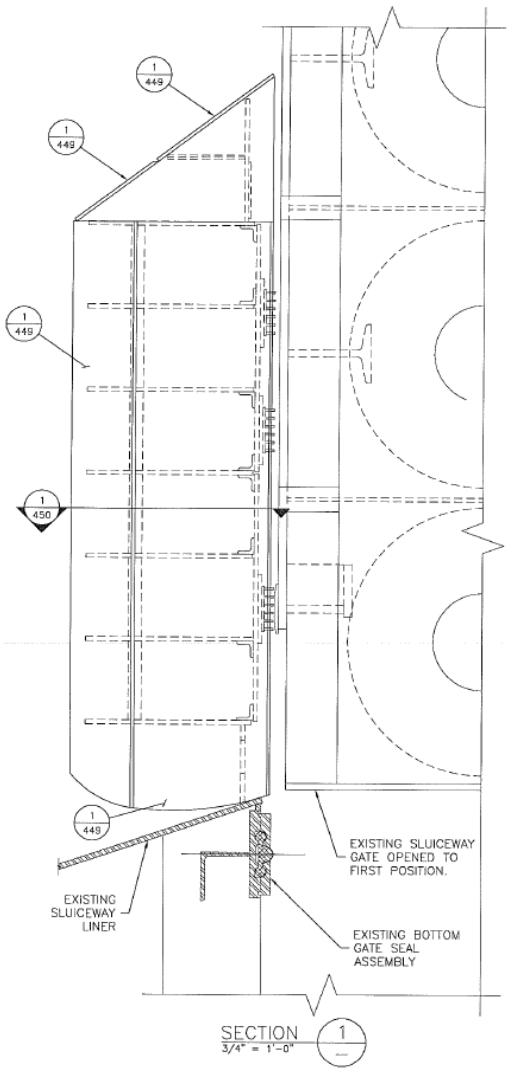


H = 18”

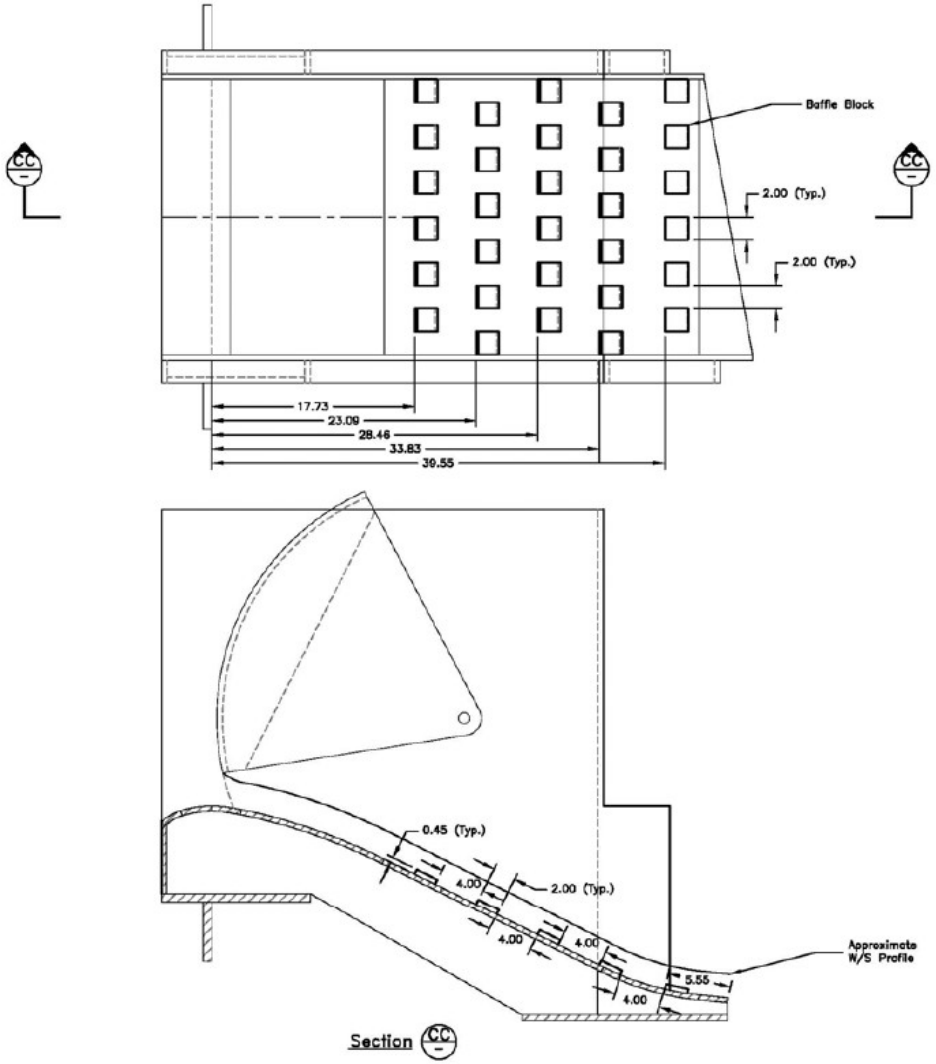


Sluiceway Modifications
Deflectors in water conveyance



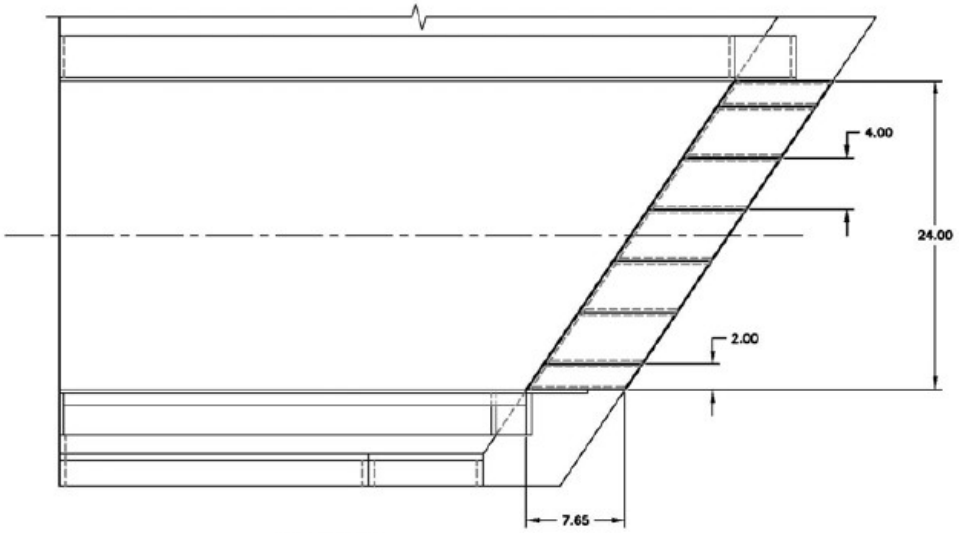

EXISTING SLUICEWAY GATE OPENED TO FIRST POSITION.
EXISTING SLUICEWAY LINER
EXISTING BOTTOM GATE SEAL ASSEMBLY
SECTION 1
3/4" = 1'-0"

Spillway Turbulence Elements Physical Model

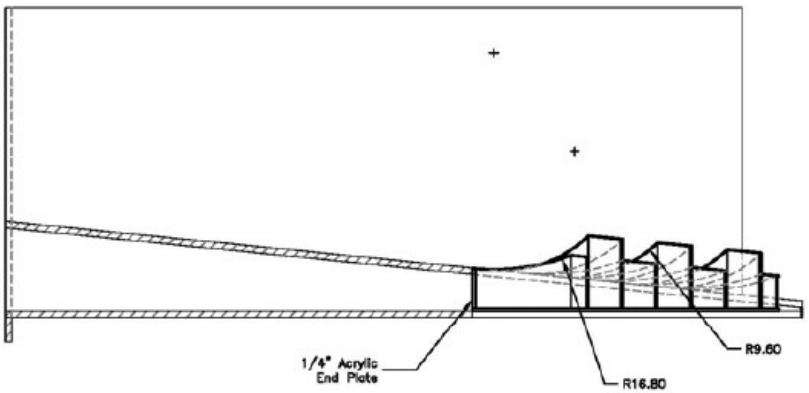


Spillway Turbulence Elements Physical Model

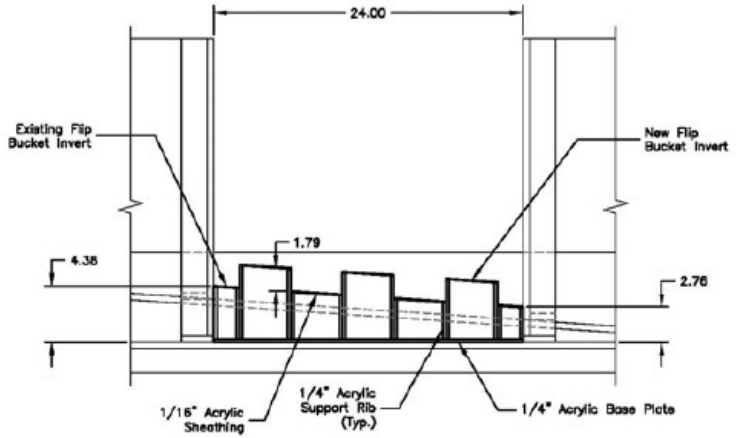
Spillway Dentated Flip Bucket



Plan View



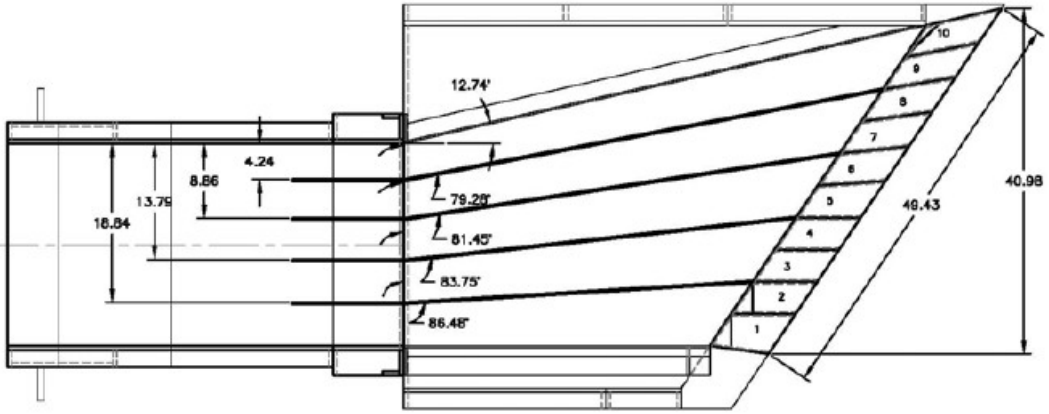
Section A



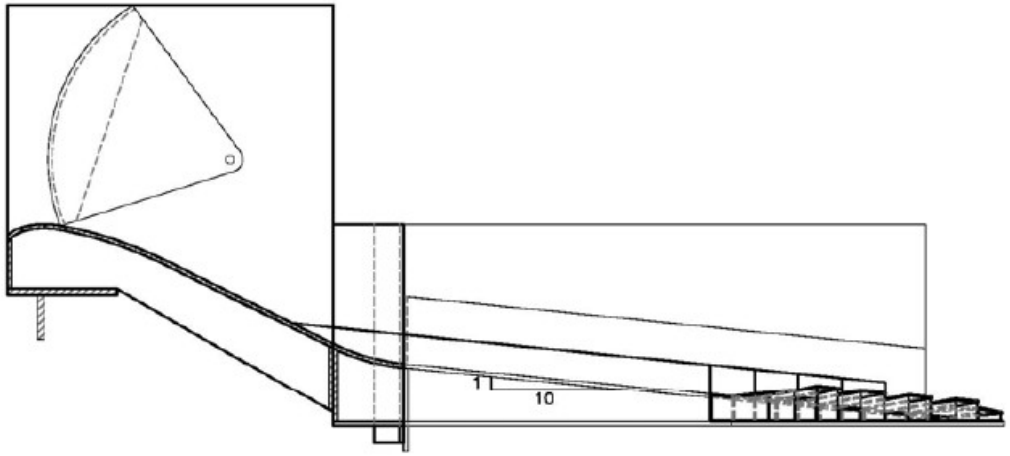
End View

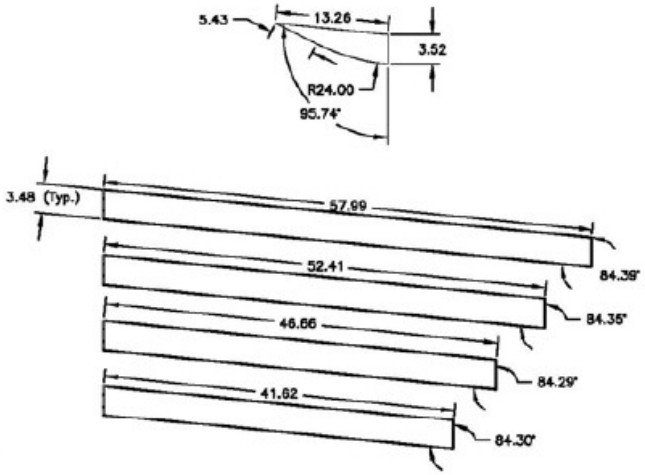
Spillway Dentated Flip Bucket

Spillway Dentated Flip Bucket w/ Widened Spillway



Plan View

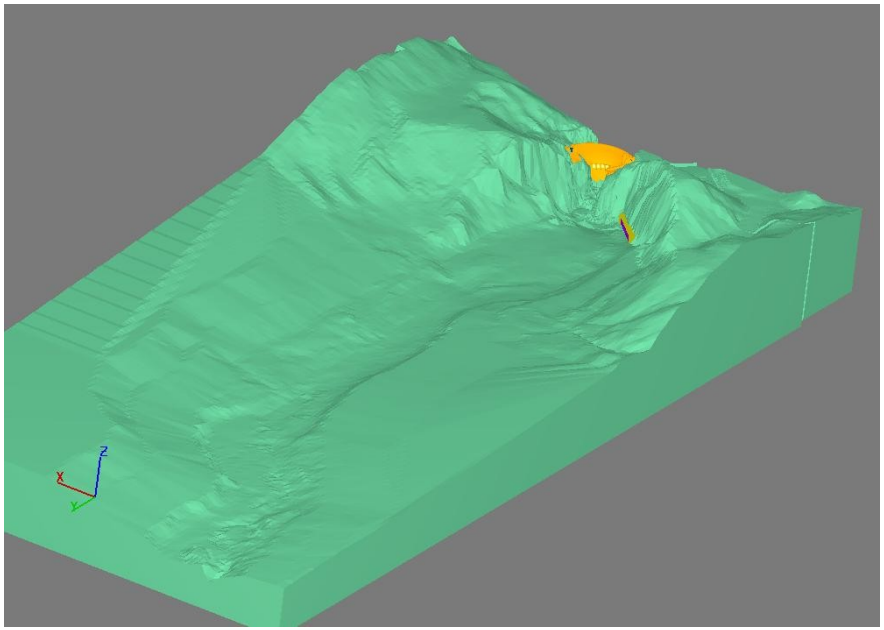




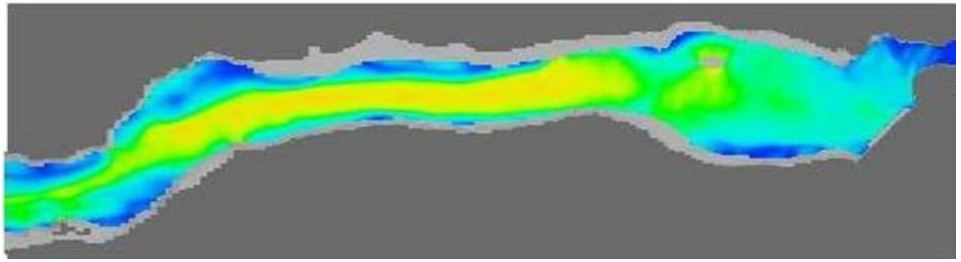
Spillway Dentated Flip Bucket w/ Widened Spillway

Overall CFD Model

Tailwater Bathymetric Surface



Surface Velocity Contours



Numerical TDG Predictive Model Under Development

Discrete Particle Tracking

1. Sprinkle buoyant history particles in air entrainment zone of jet
2. Track and record hydrodynamic history of particles
3. Export history to a spreadsheet algorithm to estimate gas transfer
4. Integrate gas transfer for each bubble to calculate total TDG

Numerical Modeling of TDG

Use source/sink terms in mass transport algorithm of FLOW-3D

1. Calculate number, size, and surface area of air bubbles from shear stress and air volume
2. Calculate gas transfer to dissolved phase
3. Apply free surface boundary condition to allow release to atmosphere
4. Transport TDG through flow field by advection-diffusion and mass transport

Summary

Suite of tools being developed and applied:

- Field TDG data analysis
- 1:25 physical model of spillways and outlets
- Detailed CFD models of spillways and outlets
- Overall CFD model/TDG predictive model

Mitigation alternatives to reduce jet and air penetration to depth:

- Sluice operations at partial gate openings
- Spillway operations at partial gate openings
- Sluice deflectors
- Spillway dentated/dispersion flip bucket